

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS

424 TRAPELO ROAD
WALTHAM 54, MASS.

ADDRESS REPLY TO:
DIVISION ENGINEER

REFER TO FILE NO.

NEDGW

SUBJECT: Repair of Flood Control Dike, Lincoln, New Hampshire

JUN 1 1960

TO: Chief of Engineers
Department of the Army
Washington, D. C.
ATTN: ENGOW-O

1. There are submitted herewith pursuant to authority contained in 1st Indorsement from Chief of Engineers to New England Division, dated 16 March 1960, to letter from New England Division, dated 18 February 1960, ten copies of Letter Design Memorandum entitled "Repair of Flood Control Dike, Lincoln, New Hampshire." The location and general plan of recommended improvements are designated in this memorandum.

2. On 8 March 1960, the Town Meeting of Lincoln voted to comply with the "abc" requirements of local cooperation set forth in Section 3 of the 1936 Flood Control Act. Formal assurances of participation will be obtained from local interests prior to construction.

3. As indicated in letter of 18 February 1960, local interests under our direction have performed emergency repairs at a cost of about \$20,000. These repairs, which were effective in preventing further damage during the 1960 Spring run-off, are being incorporated in plans for the final restoration of the dike.

4. The preparation of plans and specifications is in progress. It is anticipated that construction work on this project could be started by mid-summer 1960 and be completed within three months. Funds for construction will be requested upon the evaluation of bids received.

Incl (10 copies)
Ltr Des Memo, Lincoln, N.H.
(Cys 1-3 with plates and
photos, cys 4-10 without)

ALDEN K. SIBLEY
Brigadier General, U. S. Army
Division Engineer

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 Trapelo Road
Waltham 54, Mass.

REPAIR OF FLOOD CONTROL DIKE

EAST BRANCH PEMIGEWASSET RIVER
MERRIMACK RIVER BASIN
LINCOLN, NEW HAMPSHIRE

LETTER DESIGN MEMORANDUM

May 1960

REPAIR OF FLOOD CONTROL DIKE
EAST BRANCH PEMIGEWASSET RIVER
MERRIMACK RIVER BASIN
LINCOLN, NEW HAMPSHIRE

LETTER DESIGN MEMORANDUM

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REPAIR OF FLOOD CONTROL DIKE

EAST BRANCH PEMIGEWASSET RIVER
MERRIMACK RIVER BASIN
LINCOLN, NEW HAMPSHIRE

LETTER DESIGN MEMORANDUM

May 1960

A. PERTINENT DATA

Physical Features

1. Location. - In the Town of Lincoln, New Hampshire on the East Branch of the Pemigewasset River from the Diversion Dam of the Franconia Paper Company downstream along the existing log crib dike on the west bank of the river.

2. Type of Improvement. - Channel excavation, flank dike and reinforcement and repairs to the existing log crib dike including a rockfill cover stone.

3. Length of Improvement

a. Channel excavation	1350 feet
b. Flank dike	230 feet
c. Existing dike restoration	1350 feet

4. Hydrology

a. Maximum Flood of Record (Oct 59)	30,000 c.f.s.
b. Project Design Flood	30,000 c.f.s.

5. Channel Dimensions

a. Bottom width	150 feet
b. Side slopes	1 vertical on 2 horizontal

6. Flank Dike Dimensions

a. Top width	16 feet
b. Side slopes	1 vertical on 2 horizontal
c. Freeboard above design flood	3 feet

7. Dike Restoration Dimensions

- | | |
|---------------------------------|----------------------------|
| a. Top width | Minimum 3 feet |
| b. Side slopes | 1 vertical on 2 horizontal |
| c. Size of rockfill cover stone | Minimum 3 tons |

8. Cost Estimates

a. <u>First Costs:</u>	Federal	\$ 118,000
	Non-Federal	<u>20,000</u>
	Total	\$ 138,000
b. <u>Annual Costs:</u>	Federal	\$ 4,170
	Non-Federal	<u>1,330</u>
	Total	\$ 5,500

9. Benefits

- | | |
|----------------------------|------------|
| a. Average Annual Benefits | \$ 17,000 |
| b. Benefit-Cost Ratio | 3.1 to 1.0 |

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LETTER DESIGN MEMORANDUM

May 1960

B. PROJECT AUTHORITY

This design memorandum is submitted pursuant to authority contained in 1st Indorsement from Chief of Engineers to New England Division, dated 16 March 1960, to letter from New England Division, dated 18 February 1960, subject: "Repair of Flood Control Dike, Lincoln, New Hampshire."

C. SCOPE OF DESIGN MEMORANDUM

1. Scope. This design memorandum reviews a flood control problem along the East Branch of the Pemigewasset River in the Town of Lincoln, New Hampshire, and submits remedies for the restoration of an existing flood control dike under the provisions of Public Law 99, 84th Congress. The flood control dike constructed by private interests provides protection for the town's sole industry and source of employment, the Franconia Paper Company. Following the upper New England floods of October 23-25, 1959, a formal request was made by the Town of Lincoln, New Hampshire, and the New Hampshire Water Resources Commission requesting Federal assistance in this flood problem.

2. Topographic Survey. Plane table surveys were made, on a scale of 1" = 100', 1" = 20', and at a contour interval of 2 feet, for the area where dike repairs are recommended.

3. Geologic and Subsurface Explorations. A geological reconnaissance has been made of the subject site. Dike repairs will not require subsurface explorations.

4. Economic Investigations. Damage surveys were made following the 1936 and 1959 floods. The dike prevented substantial losses from recurring in the recent floods of 23-25 October 1959. Economic investigations developed losses which would result if the dike were to fail under present plant operations.

5. Field Reconnaissance and Office Studies. Field reconnaissances have been made of the problem area and site of potential improvements. Office studies consisted of hydrologic and hydraulic analyses, design of improvement, and estimates of quantities and costs of proposed construction.

6. Conferences with Local Interests. Close liaison has been maintained with state and town officials, plant officials and other interested parties. Plans for the repair work have been discussed with representatives of these agencies. Desires of local interests are described in Section T.

D. PRIOR REPORTS

There are no prior reports for a local protection project at the Lincoln, New Hampshire site. The New England-New York Inter-Agency Committee Report dated 23 February 1955, which was prepared under the directive contained in Presidential letter of 2 October 1950, Part 2, Chapter VI, includes information that additional flood protection is needed but not economically feasible on the East Branch of the Pemigewasset River above Lincoln, New Hampshire.

E. DESCRIPTION OF AREA

7. Geography. Lincoln, New Hampshire is situated in the upper watershed of the Merrimack River Basin, 80 miles north of Concord, New Hampshire and 150 miles northeast of Boston, Massachusetts. The East Branch of the Pemigewasset River (drainage area of 115 square miles) joins with the Pemigewasset River (drainage area 35 square miles) in North Woodstock one mile from Lincoln, New Hampshire, about 170 miles upstream of the mouth of the Merrimack River. A map of the Merrimack River Basin is shown on Plate 1.

8. Project Area. The Franconia Paper Company, employing 600 full-time workers at the plant, and 300 part-time woodsmen, is located on the right bank of the East Branch about $1\frac{1}{4}$ miles upstream of the Pemigewasset River. The company is the successor to Parker Young Company which suffered severe losses in the 1927 flood and substantial losses during the 1936 flood which contributed to financial difficulties resulting in bankruptcy. Following the 1936 flood the Franconia Paper Company constructed along the west (right) bank of the river approximately

2,000 l.f. of log crib dike which was entombed with stone. The crib dike acts as a deflecting shield preventing rushing waters from flanking the west bank, entering a log pond upstream of the mill, and demolishing the mill itself. The protective works extend for approximately 2,000 feet downstream from a low diversion dam located 1/2 mile upstream of the plant. (See Plate 2) About 1-3/4 miles upstream from the plant is the site of #1 dam used primarily as a power dam which houses head gates and equipment for a penstock that runs for about 9,500 l.f. into the generating rooms of the mill. Both the diversion dam and #1 dam are of little value as flood retention reservoirs.

9. Topography. The project is located in the White Mountain section of the New England Physiographic Province where mountainous elevations of from 2,000 to over 4,000 feet dominate the topography. The mountains have steep grades covered with timber lands with many large brooks and streams discharging high speed erosive type flows into the river.

10. Geology. This section of the White Mountains is a region of hard, igneous and metamorphic rocks, maturely dissected by erosion and subjected to the modifying effects of both mountain and continental glaciation. The overburden of the region is predominantly unsorted glacial drift (till), thinly deposited on the mountains but locally to great thicknesses in the mountain valleys. The valley of the East Branch of the Pemigewasset River at Lincoln approaching its confluence with the main river becomes broad and plain-like at about elevation 750 from deposition of glacial melt waters in the form of poorly sorted sands, gravels and cobbles which are being gradually eroded and redeposited by the river.

11. Maps. The East Branch of the Pemigewasset River and its watershed are shown on standard quadrangle sheets of the U. S. Geological Survey (1:62,500) and on standard quadrangle sheets of the Army Map Service (1:50,000).

F. CLIMATOLOGY

12. General. The Pemigewasset River Basin has a variable climate characterized by frequent but generally short periods of heavy precipitation. The basin lies in the path of the "prevailing westerlies" and is exposed to the cyclonic disturbances that cross the country from west or southwest toward the east or northeast. The area is also subject to coastal storms that travel up the Atlantic seaboard in the form of hurricanes of tropical origin or storms of extra tropical nature, often called "northeasters".

The winters are moderately severe with sub-zero temperatures common. The spring melting of the winter snow cover occurs generally in the months of April and May. The summers are rather warm with extreme temperature readings of about 100°F.

13. Temperature. The average annual temperature of the area is about 43°F. The average monthly temperature varies from 67°F. in July to about 19°F. in January. Extremes in temperature range from occasional highs slightly in excess of 100°F. to infrequent lows in the minus "thirties". Table 1 shows the monthly mean, maximum and minimum and annual temperatures at Woodstock, New Hampshire, elevation 720 feet, mean sea level (m.s.l.), about 5 miles south of Lincoln, New Hampshire, which has an elevation of 830 feet, m.s.l.

TABLE 1

MONTHLY TEMPERATURES
(Degrees Fahrenheit)

WOODSTOCK, NEW HAMPSHIRE

Elevation 720 feet, m.s.l.

17 Years of Record

<u>Month</u>	<u>Mean</u>	<u>Maximum</u>	<u>Minimum</u>
January	19.2	60	-31
February	20.5	61	-28
March	30.4	83	-25
April	41.0	88	1
May	52.6	95	18
June	62.0	95	26
July	67.2	97	32
August	65.1	100	31
September	57.4	93	23
October	47.4	89	12
November	35.3	80	3
December	22.3	61	-29
Annual	43.4	100	-31

14. Precipitation. The mean annual precipitation over the area varies from about 46 inches in the lower elevations to about 60 inches in the upper elevations and is uniformly distributed throughout the year. Table 2 summarizes the monthly precipitation at Lincoln, New Hampshire, for the 38 years of record.

TABLE 2
MONTHLY PRECIPITATION RECORD
(In Inches)

LINCOLN, NEW HAMPSHIRE

Elevation 830 feet, m.s.l.

38 Years of Record

<u>Month</u>	<u>Mean</u>	<u>Maximum</u>	<u>Minimum</u>
January	3.60	7.14	0.95
February	2.89	4.70	1.15
March	3.63	11.72	1.16
April	3.69	6.00	0.42
May	3.77	7.09	1.28
June	4.07	11.59	1.46
July	4.28	8.51	1.38
August	4.03	7.63	1.00
September	4.59	12.39	0.90
October	3.64	10.16	0.43
November	4.14	9.12	0.76
December	3.76	8.69	1.34
Annual	46.09	56.44	35.63

15. Snowfall. Most of the precipitation during the winter months is in the form of snow. The average snowfall of the basin varies from about 86 inches in the valleys to about 170 inches in the mountains. The water equivalent of the snow cover over the basin in the early spring varies from about 4 inches to about 11 inches, with an average of about 7 inches. Table 3 shows the mean annual snowfall in inches at Lincoln, New Hampshire for 17 years of record.

TABLE 3

MEAN MONTHLY SNOWFALL
(Average Depth in Inches)

LINCOLN, NEW HAMPSHIRE
Elevation 860 feet, m.s.l.
17 Years of Record

<u>Month</u>	<u>Snowfall</u>
January	22.1
February	19.8
March	15.0
April	4.9
May	0.2
June	0
July	0
August	0
September	0
October	0.8
November	6.4
December	16.6
Annual	85.8

16. Storms. The New England area experiences three general types of storms; continental, coastal, and those associated with thunderstorms which may be of local origin or the result of a weather front. Continental storms originate over the United States and southwestern Canada and move in a general easterly and northeasterly direction. These storms may be rapidly moving intense cyclones, or they may be weak and nearly stationary. They are not limited to any particular season or month but follow one another at more or less regular intervals with variable precipitation intensity through the year. Of the coastal storms, tropical hurricanes constitute an infrequent but very important potential for flood producing precipitation, particularly from August through October. Coastal storms of an extra-tropical nature differ from hurricanes principally in that they originate off the Carolina coastline. These storms, which have been the prime flood producer in the Pemigewasset River Basin, occur most frequently during autumn, winter and spring months. Thunderstorms may be of local origin or associated with weather fronts during the summer months.

G. RUNOFF

17. Discharge Records. Discharge records for the East Branch of the Pemigewasset River near Lincoln, New Hampshire (D.A. 104 sq. mi.) have been published by the U. S. Geological Survey for the period of record November 1928 through March 1953. This gaging station was abandoned after the March 1953 flood due to destruction of the hydraulic control. Discharge records have also been published for the Pemigewasset River at Woodstock, New Hampshire, drainage area 193 square miles, from October 1939 to date. This gaging station is about 4.3 miles below the confluence with the East Branch. Stream-flow records at these gaging stations are summarized in Table 4.

TABLE 4

STREAMFLOW RECORDS

<u>Location of Gaging Station</u>	<u>Drainage Area (sq. mi.)</u>	<u>Period of Record</u>	<u>Discharge (c.f.s.)</u>		
			<u>Mean</u>	<u>Maximum</u>	<u>Minimum</u>
East Branch Pemigewasset River near Lincoln, N.H.	104	1928-1953	298	17,000	13
Pemigewasset River at Woodstock, N.H.	193	1939-	42,518	42,000 (1)	64

(1) Instantaneous Discharge, October 1959

18. Runoff. The annual runoff for 24 years of record through March 1953 for the gage at Lincoln, New Hampshire varied from 26.33 to 47.01 inches with a mean of 38.96 inches. The annual runoff for the 19 years of record through September 1958 for the gage at Woodstock, New Hampshire, varied from 24.90 to 47.50 inches with a mean of 36.47 inches. Table 5 shows a summary of the mean, maximum and minimum monthly and annual runoff in inches for the period of record for the U.S.G.S. gaging stations on the East Branch of the Pemigewasset River near Lincoln, New Hampshire and on the Pemigewasset River at Woodstock, New Hampshire.

TABLE 5

MONTHLY RUNOFF
(In Inches)

<u>Month</u>	<u>East Branch Pemigewasset River</u> <u>near Lincoln, New Hampshire</u> (D.A. = 104 sq. mi.) Nov 28 - Mar 53			<u>Pemigewasset River</u> <u>at Woodstock, N.H.</u> (D.A. = 193 sq. mi.) Oct 39 - Sep 58		
	<u>Mean</u>	<u>Maximum</u>	<u>Minimum</u>	<u>Mean</u>	<u>Maximum</u>	<u>Minimum</u>
January	1.92	4.76	0.24	1.67	4.01	0.33
February	1.10	2.64	0.28	1.10	2.13	0.32
March	3.31	22.48	0.39	2.72	10.15	0.39
April	7.46	11.38	3.27	7.74	11.74	4.43
May	9.54	16.66	2.71	8.22	14.24	2.41
June	3.28	5.91	1.33	2.92	5.24	0.92
July	1.65	3.12	0.77	1.60	3.78	0.57
August	1.38	3.57	0.50	1.23	3.43	0.45
September	1.79	9.86	0.42	1.63	7.01	0.37
October	2.26	6.12	0.48	1.90	5.09	0.39
November	3.14	7.60	0.83	3.21	6.56	0.70
December	2.37	6.50	0.49	2.56	7.95	0.46
Annual	38.96	47.01	26.33	36.47	47.50	24.90

H. HISTORY OF FLOODS

19. General. The upper Merrimack River Basin including the Pemigewasset River and East Branch is subject to annual spring freshets due to snow melt and often augmented by rainfall. However, the majority of large floods in the East Branch have been produced by coastal storms of tropical and extra tropical origin.

20. Floods of Record. The East Branch of the Pemigewasset River has experienced nine major floods in 32 years, a summary of which is shown in Table 6. The two largest floods occurred in October 1959 and November 1927. The flood of 24 October 1959 was estimated by the U. S. Geological Survey to have had an instantaneous peak of 24,200 c.f.s. at the No. 1 Franconia Paper Corporation Dam, located upstream of the problem area. However, due to ambiguities in data, and based on approximate slope-area determinations and related to discharges at other locations, it is believed that the peak discharge may have been nearly 30,000 c.f.s. The peak discharge during the flood of November 1927 is unknown but is reported by local residents to have been the largest flood prior to October 1959. Hydrologic analyses of the two floods in the upper Pemigewasset River indicate that the peak flow in the East Branch during the October flood was probably slightly in excess of that during the November 1927 flood.

TABLE 6

MAJOR FLOODS

EAST BRANCH PEMIGEWASSET RIVER

LINCOLN, NEW HAMPSHIRE

<u>Flood</u>	<u>Peak Discharge</u>	
	<u>(c.f.s.)</u>	<u>(c.s.m.)</u>
November 1927	unknown	
3 May 1929	9,800	94
19 March 1936	17,000	163
21 September 1938	16,300	157
3 May 1940	9,100	88
9 November 1943	10,300	99
1 June 1952	10,600	102
24 October 1959	24,200 (1)	221

(1) U. S. Geological Survey Estimate

I. FLOOD FREQUENCY

A flood frequency curve for the Lincoln gaging station was calculated by Beard's method from a 24-year record. The mean and standard deviation were adjusted by use of the long record on Pemigewasset River at Plymouth, New Hampshire. The adjusted statistics have a reliability equivalent to 42 years of record. A skew coefficient of 0.6 was adopted on the basis of a regional study, including seasonal analyses, of flood data. The lower portion of the flood frequency curve for the Lincoln gaging station was determined graphically from the partial duration series. Discharges were adjusted by the 0.7 power of the ratio of drainage areas to obtain the flood frequency curve for the damage zone. The flood of record has an estimated average recurrence interval slightly in excess of 100 years.

J. PROJECT DESIGN FLOOD

21. Hydraulics of Flood Problem. The flood problem at the project site is caused by the stream alignment coupled with the steep channel slope. Immediately downstream from the diversion dam the stream makes a moderate bend to the left which causes the high velocity flow to concentrate along the dike on the right (west) bank. The energy gradient through the project reach during major floods has an estimated slope of about 1.6 percent, which is sufficient to produce supercritical flow. Realignment of the channel is impractical because of solid ledge outcrops along the left bank and the bottom. Relocation of the dike is equally impractical due to the structural layout of the dam, headworks and penstock of the Franconia Paper Corporation.

22. Standard Project Flood. Although not used for project design, the magnitude of a standard project flood was roughly determined to indicate the potential of the area. The standard project storm rainfall was compared with the October 1959 storm. The standard project storm rainfall for the 115 square mile drainage area would total 9.50 inches for a 24-hour period and the maximum six-hour value would be 7.86 inches. The October 1959 storm was centered over the higher elevations about 10 miles to the northeast of the East Branch watershed. The maximum total storm precipitation was 10.79 inches and occurred at Pinkham Notch, New Hampshire, with 8.98 inches falling in a 24-hour period. The maximum six-hour amount was 3.46 inches at the same location. Based on comparison of rainfall intensities in a standard project storm and the 1959 storm, it is estimated that a standard project flood at the project site would likely exceed 50,000 c.f.s.

23. Design Flood. Because of the character and magnitude of the project the adopted design flood was the October 1959 flood. The water surface profile of the above flood along the right bank closely paralleled the top of the existing dike. It is considered that a reasonably

high degree of protection will be provided by restoring the existing dike to the record flood level plus freeboard.

24. Hydraulic Design

a. Water Surface Elevations. The design water surface elevation was developed from flood marks obtained after the October 1959 flood. The water surface profile along the right (west) bank was found to closely parallel the top of the existing dike. High water marks on the left bank indicate that the water surface about 350 feet downstream of the diversion dam was superelevated in excess of two feet due to the curvature of the stream.

b. Channel Velocity. The average channel velocity through the project area during the October 1959 flood was computed using conventional hydraulic formulae. The water surface slope during this flood was determined from field surveys to be about 1.6 percent and the roughness coefficient was estimated to vary between .035 and .045. The computed average velocity ranged between 18 and 23 feet per second. These are super-critical velocities and probably produced complex flow conditions in the channel. The serious erosion of the dike along the outer radius of the channel was undoubtedly produced by the high velocities, the concentration of flow along the outside of the bend, and the obvious movement of the bed load of stones. (See Photographs Nos. 1, 2 and 3.)

c. Freeboard. The design grade of the dike was set three feet above the design water surface profile to prevent overtopping by wave action. This top of dike grade is considered necessary because of factors inherent in the complex, high velocity flow in the curved channel.

d. Slope Protection. Slope protection will be provided by a 3-foot layer of quarried rock. Applying the estimated flow velocities to the USBR curve on Hydraulic Design Chart 712-1, "Hydraulic Design Criteria", requires a stone weight in excess of 6,000 pounds. The selection of stone weighing a minimum of three tons appears reasonable when considering the steepness and curvature of the channel, and susceptibility to attack by large stones and ice carried along by the high velocity flow. Severe channel erosion is evident at several locations on the East Branch, and the recent destruction of the U.S.G.S. gaging station control is a noteworthy example.

K. FLOOD LOSSES

According to local interests, the flood of November 1929 caused a direct loss estimated at \$1,000,000 to the then Parker Young Company. However, owing to the transfer of ownership of the mill accomplished

in 1946, there has been no retention of past records which can be utilized in a report breakdown without estimations. Plant officials have prepared estimates based on their present operation which indicate that should the river leave its present source and swing towards the mill as it did in 1927 a total loss of \$1,500,000 could result. Office evaluation of damage and frequency of occurrence reveals that without the dike, the stream would overflow the bank upstream of the plant and come down through the pond into the plant about once in every nine years. Damages would vary from \$50,000 for a 10-year flood to \$1,000,000 for a flood of 100 year frequency. The restoration of the dike would eliminate damages from floods in this frequency range.

L. EXISTING FLOOD CONTROL IMPROVEMENTS

25. Federal and State Improvements. There are no existing Corps of Engineers or other Federal or state flood control improvements in the East Branch of the Pemigewasset River.

26. Local Improvements. The Franconia Paper Company has performed emergency repairs to their protective dike to prevent failures during spring freshets or other minor floods. This local work, coordinated with the New England Division and at a cost to local interests of approximately \$20,000, will provide a portion of the permanent repairs.

M. IMPROVEMENT DESIRED

Several meetings have been held between representatives of the Corps of Engineers and local interests. According to plant officials, the flood of 24 October 1959 was as severe as any previously experienced. The Mill itself escaped serious damage because of the log-crib dike protection. The flood, however, has caused serious erosion to this protective shield and it is of prime concern to plant officials who fear that even minor flooding will cause its failure and thereby imperil plant operations. The Selectmen of the Town of Lincoln are most desirous that the restoration of this dike be undertaken to insure the security of the Franconia Paper Company, which supplies 80% of the tax revenue of the Town and represents the sole employment for Lincoln and neighboring towns.

N. FLOOD PROBLEM AND SOLUTIONS CONSIDERED

27. Flood Problem. The log crib at the Franconia Paper Company has prevented damage to the plant in each instance since its construction. During the flood of 24 October 1959 damages to the dike comprised three major elements:

a. All of the stones and boulders on the river side of the wood crib were washed away for a distance of about 150 feet extending from the west abutment of the diversion dam.

b. Between about 150 to about 500 feet downstream from the dam, portions of the stone protection on the river side of the dike were washed away without exposing the wood crib.

c. In the next 550 feet (i.e. 500-1050 feet downstream of the dam) all of the stone and boulders on the river side of the wood crib were washed away. At two locations in this reach, the wood crib was undermined and the crib fill washed away causing minor break-throughs.

d. Beyond a point 1,100 feet downstream from the dam, the dike was not damaged although some minor overtopping occurred. Much of the stone and boulders from the damaged reaches of the dike were carried by the flood waters and deposited downstream along the heel of the undamaged portion of the dike. It is evident that some boulders weighing as much as 4 tons and many boulders weighing 1 ton or more were transported by high velocities.

28. Solutions Considered

a. General. Consideration has been given to all practicable methods of solving the flood problem at Lincoln. Channel realignment is complicated by the presence of the existing diversion dam and by extensive ledge outcrops along the channel bottom and the east bank. Reservoir control to be effective is impractical in this rugged mountain valley and is extremely costly. Diversions of flood waters would be too extensive in scope to become justified. Excavation in the river channel to provide greater water-way produced insufficient hydraulic benefits for the costs incurred owing to the slope of the river which offers a greater influence and control upon river velocities and high water elevations. Construction of deflector walls was found to be too costly. The most practical solution resolved to be the utilization of the existing stone and log-crib dike by restoration to consist of cover stone larger in size than the stone previously used. Minor improvement is contemplated in the channel area by the removal of loose stone, some portions of which will be utilized in the dike restoration.

O. PROPOSED REPAIRS

29. General Description. Plate 2 shows a general layout and typical sections of the recommended plan of improvement which will consist principally of the reinforcement of the dike for 1350 l.f. It would include 230 feet of flank dike which will run north from the west abutment of the diversion dam to high ground. The dike will incorporate an existing access road which was constructed by local interests in the performance of their emergency repairs. The dike will provide protection for an existing low spot to the rear of the dike and thereby prevent flows from flanking protective works

as was experienced during the recent flooding. Included in the improvement is the placement of stone along the west abutment of the dam to stabilize and protect vertical timber siding containing earth fill. An existing sluice gate which controls the entrance of the water into the diversion canal will provide closure during flood periods.

30. Dikes. The 1350 l.f. of existing dike which is to be restored consists of a timber crib filled with stones and boulders. When initially constructed, the river side face of the crib was sheathed with planks; however, only 200 feet of sheathing now remain. The crib is composed of rough timber 12 inches or more in diameter, held together with iron pins. In general the crib is well built and in good condition. The proposed improvement will consist of the placement of a 3' single layer of cover stone, minimum 3-ton, which will be laid on a 2 to 1 side slope. The dike top width which varies from 10 to 35 feet will remain as is except for cover stone which will be keyed in at the top to provide a 3' freeboard above design flood. The cover stone will rest upon 2' of bedding stone. The bedding stone will be composed of river cobbles and boulders, some of which will come from channel clearing. These boulders in turn rest upon the remaining log crib and smaller stone and gravel that make up its composition. Sheathing where existing will be removed to facilitate stone placement and insure proper placement of bedding stone.

31. Flank Dike. The flank dike will begin at the west abutment and follow for 230 l.f. to high ground. The dike, which utilizes an existing access road, will have a 16-foot top width and 2 on 1 side slopes. It will be composed of sand and gravelly fill and a stone covering 1'-6" thick.

32. Channel Excavations. Minor improvement of the channel area is contemplated by the removal of boulders and stone in the reach where repair work is planned. Portions of the material will be utilized as bedding stone for the restoration work. The excess volume of this material will be spoiled downstream along the undamaged reaches of the dike.

33. Slope Protection at the West Abutment. It will be necessary to stabilize and protect vertical timber siding at the west abutment of the diversion dam. The timber siding which retains earth fill will be reinforced by a 2 on 1 side slope of 3-ton cover stone resting upon bedding stone.

P. ESTIMATES OF FIRST COST AND ANNUAL CHARGES

Estimates of Federal and non-Federal first costs and annual charges are given in Table 7. These estimates have been prepared on the basis that local interests would bear the entire cost of

relocations and alterations to utilities, furnish all lands and rights-of-way necessary for construction and operation of the project, including disposal areas for excavated materials not used in the dikes, and operate and maintain the project after completion.

Unit prices used in estimating costs are based on average bid prices for similar work in the same general area. The adopted unit prices are adjusted to the 1960 price level. It is noted that increases in the cost of cover stone over earlier estimates has been occasioned by the following reasons:

a. A larger volume required owing to the change in dike slope from a 1 vertical on 1 horizontal to a 1 vertical on 2 horizontal.

b. A review of the availability and capabilities of local quarries supplying cover stone indicates it will be necessary to engage other outside sources, thereby resulting in higher unit price/ton.

Annual charges are based on an annual interest rate of 2.5 percent for Federal and 4% non-Federal, with amortization of the project cost distributed over a 50-year period. A summary of first costs and annual charges are given in Table 7 following:

TABLE 7
EAST BRANCH PEMIGEWASSET RIVER
COST ESTIMATE FOR REPAIR OF FLOOD CONTROL DIKE

<u>FIRST COST</u> (1960 Base)				
<u>FEDERAL</u>				
<u>Item</u>	<u>Quantity</u>	<u>Unit</u>	<u>Unit Price</u>	<u>Estimated Amount</u>
Site Preparation	1	Job	L.S.	\$ 1,600
Dike Excavation, Unclassified	4,000	cu yd	1.00	4,000
Channel Excavation, Unclassified (includes the spoiling of material not utilized in restoration)	6,000	cu yd	1.00	16,000
Fill (gravelly sand)	400	cu yd	1.50	600
Gravel Road	100	cu yd	2.00	200
Rock Fill, River Cobbles & Boulders	4,000	cu yd	1.00	4,000
Rock Fill, Cover Stone	10,000	Tons	7.00	70,000
Subtotal				\$86,400
Contingencies				13,000
				\$99,400
Engineering & Design				10,000
Supervision & Administration				8,600
TOTAL ESTIMATED FEDERAL FIRST COST				\$118,000

TABLE 7 (cont'd)

NON-FEDERAL

<u>Item</u>	<u>Amount</u>
Repairs accomplished by others	\$20,000

ANNUAL CHARGESFEDERAL

Interest (2.5% x \$118,000)	\$ 2,950
Amortization (1.026% x \$118,000)	<u>1,220</u>
Total	\$ 4,170

NON-FEDERAL

Interest (4.0% x \$20,000)	800
Amortization (.0655% x \$20,000)	130
Maintenance	<u>400</u>
Total	\$ 1,330

TOTAL ANNUAL CHARGES \$ 5,500

$$\text{Benefit-Cost Ratio} = \frac{17,000}{5,500} = 3.1 \text{ to } 1.0$$

Q. ANNUAL BENEFITS

The Franconia Paper Company precariously located adjacent to the river is susceptible to heavy damages from the larger floods unless the dike is permanently restored. Without the dike, the stream would overflow the bank upstream of the plant and come down through the pond into the plant about once in every nine years. Damages would vary from \$50,000 for a 10-year flood to \$1,000,000 for a flood of 100-year frequency. The restoration of the dike would eliminate damages from floods in this frequency range. Overtopping from the rarer floods could cause some minor damages. Annual damages in the 10-year to 100-year range are estimated at \$17,000 and can be credited as annual benefits to the dike. In addition to the physical and associated damages prevented at the plant, the economy of the area is affected. In a major flood such as 1927, 1936 or 1959 without the dike, the mill would be closed for 3 to 4 months for extensive repairs and rehabilitation. The loss of purchasing power of the employees and their families would be reflected in Lincoln, North Woodstock, Plymouth, New Hampshire, and other trading centers in the region. The development of the region is such that the unemployed could not be readily absorbed in other activities within the area.

R. SCHEDULES FOR DESIGN AND CONSTRUCTION

The preparation of contract plans and specifications for the project is in progress. It is proposed to advertise the project by the end of June 1960. Construction of the project would be accomplished under a single contract to be awarded by mid-summer of 1960. The work will be completed in three months. All funds for the construction of the project will be requested upon evaluation of bids received. Expenditures are estimated as follows:

Total Estimated Expenditures by End of FY 1960	\$ 10,000
Construction FY 1961	<u>108,000</u>
TOTAL	\$118,000

S. OPERATION AND MAINTENANCE

Maintenance of the project will be the responsibility of local interests. In the 23 years since the construction of the dike, periodic maintenance has been performed by the paper company. This maintenance has consisted of replacement of earth and rock after erosion and damage by flood flows. It is understood that on three occasions expenditures of \$5,000, \$10,000 and \$5,000 were made for maintenance of the existing project. Periodic inspections will be made to assure that adequate maintenance is performed in accordance with regulations prescribed by the Secretary of the Army. The estimated maintenance cost, to be borne by local interests, is \$400 annually.

T. LOCAL COOPERATION

The Town of Lincoln, with a population of 1,500 people, and the Town of Woodstock, with 900 inhabitants, are heavily dependent on the Franconia Paper Company for subsistence. The Town officials together with officers of the industry have undertaken repairs of other upstream dams and hydro-power facilities as well as the emergency repairs to the dike. During the Town Meeting held on March 8, 1960, the town voted to comply with the local cooperation that is required, and in conjunction with the industry will provide the standard assurances such as lands, easements, and rights-of-way, the hold and save clause, and the maintenance and operation of the completed works. Local interests desire that their expenditure of approximately \$20,000 for emergency repairs following the 1959 flood be considered as a contribution towards local participation.

U. CONCLUSIONS

The restoration and repair of the existing flood control dike at the Franconia Paper Corporation is economically justified. The direct benefits accruing from the project would result primarily from flood protection afforded to the paper mill. However, the direct benefits to the Town of Lincoln would be large because Franconia Paper Corporation represents the sole subsistence and livelihood for the town.

V. RECOMMENDATIONS

It is recommended that repair of the dike at Lincoln, New Hampshire, as submitted in this report, be authorized under the provisions of Public Law 99, 84th Congress, and that additional funds of \$108,000 be allotted for construction. It is further recommended that expenditures already provided by local interests for emergency repairs be credited as their portion of financial participation.